State of Louisiana

Coastal Protection and Restoration Authority (CPRA)

2016 Operations, Maintenance, and Monitoring Report

for

Sabine Structure Replacement

State Project Number CS-23
Priority Project List 3

February 2016
Cameron Parish

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Suggested Citation:

Miller, M., Broussard, D. and Pontiff, D. 2013. *2013 Operations, Maintenance, and Monitoring Report for Sabine Structure Replacement (CS-23), Louisiana Coastal Protection and Restoration Authority of Louisiana, Office of Coastal Protection and Restoration, Lafayette, Louisiana* 52 pp.

2016 Operations, Maintenance, and Monitoring Report
For
Sabine Structure Replacement (CS-23)

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I. Introduction

The Replace Hog Island Gully, West Cove and Headquarters Canal Structures (CS-23) project area is located within the Sabine National Wildlife Refuge, approximately 9 mi (14.5 km) south of the town of Hackberry in Cameron Parish, Louisiana (Figure 1). Established on December 6, 1937, the Sabine Refuge is bound on the east by Calcasieu Lake, on the west by Sabine Lake, on the north by broken marsh, and on the south by pasture land and coastal ridges.

The project area was characterized as fresh to intermediate marshes dominated by *Cladium mariscus* (Jamaica sawgrass) (O'Neil 1949). The Black Lake area, located north of the project, experienced an 81% reduction in the acreage of emergent wetlands between 1952 and 1974 (Adams et al. 1978). By 1972, the Black Lake area was characterized as brackish marsh (Chabreck and Linscombe 1978). A number of factors such as salinity stress, erosion, subsidence, burning and hydrologic modification influenced this habitat change.

Water management by weirs was initiated in the 1970's to control flows through Hog Island Gully, West Cove Canal, and Headquarters Canal. By the 1990's, these structures had corroded with the continuous exposure to saline water to the extent that they were inoperable or almost inoperable.

Due to the detrimental impacts of excess salinity on brackish and intermediate marshes, the ability to occasionally reduce or halt the inflow of saline water is critical. This level of control was not available with the original structures. The inability to manipulate gate structures jeopardized the integrity of thousands of acres of interior brackish and intermediate marshes. The estimated subsidence rate in the project marshes ranges between 0.12 in/yr and 0.16 in/yr (0.32 and 0.42 cm/yr) (Penland et al. 1989).

Because of the restricted cross-sectional area of the pre-existing structures and culverts, the lower elevation interior marshes experienced longer periods of vegetative water logging stress than the marshes located east of Highway 27. The pre-existing structures afforded the primary avenues for drainage and were inadequate to provide sufficient discharge to evacuate excess water. Due to the project area not being fully enclosed, secondary drainage for the area could occur to the west through Sabine Lake via North, Central and South line canals.

In May 1999, the US Fish and Wildlife Service (USFWS) completed the environmental assessment (EA) plan addressing the Replacement of Water Control Structures at Hog Island Gully, West Cove Canal, and Headquarters Canal (CS-23) (USFWS 1999). The plan called for the complete removal of the Hog Island Gully Structure, West Cove Canal Structure, and Headquarters Canal Structure and replacement with additional structures and culverts to provide larger cross sections for water removal and to minimize saltwater intrusion.

The replacement structures should be operated to more effectively discharge excess water, increase cross sectional area for ingress and egress of estuarine dependent species and more effectively curtail saltwater intrusion into the interior marshes.

Construction began in November 1999 and was completed on the Hog Island Gully, West Cove, and Headquarters Canal structures in August 2000, June 2001, and February 2000, respectively. There were however operational issues after construction at the Hog Island Gully and West Cove structures due to electrical service problems and operating nut failures which prevented the structures from being operated as designed. Hurricanes Rita (2005) and Ike (2008) exacerbated the damage to the structures. After various post-construction maintenance events and an extensive refurbishment, which included electrical component replacement and slide gate conversion from one to two stems, in April 2011, the Hog Island Gully and West Cove structures have been repaired and are fully operational. Routine openings by the USFWS began in December 2011.

Currently, high saline waters can be controlled, water discharge capacities have been increased and vegetative stress through water logging can be minimized which should enhance emergent and submerged vegetative growth.

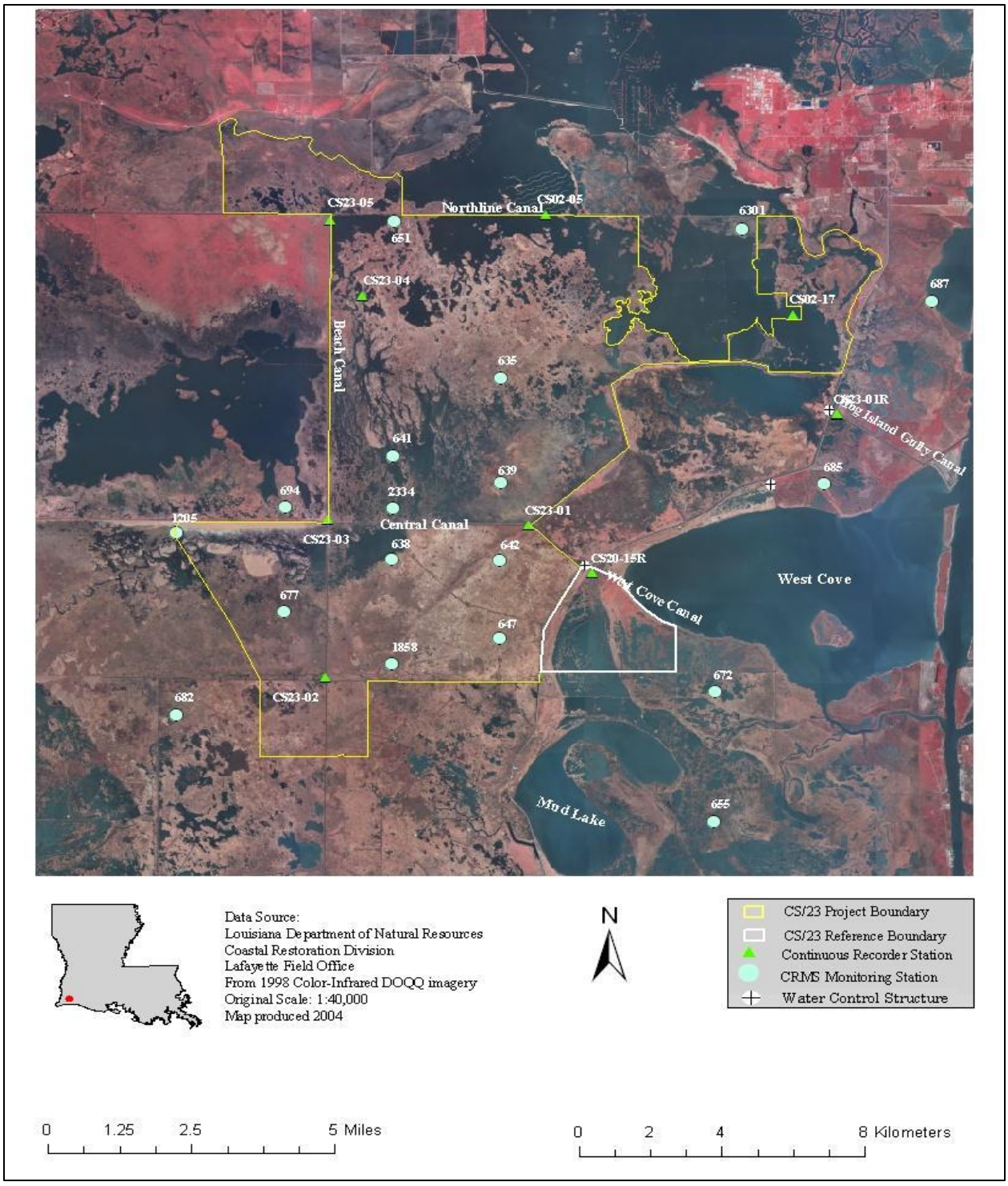


Figure 1. Replace Hog Island Gully, West Cove and Headquarters Canal Replacement Structures (CS-23) project features, CRMS Sites, project area boundaries and reference area boundaries.

II. Maintenance Activity

a. Project Feature Inspection Procedures

The purpose of the annual inspection of the Sabine Refuge Structure Replacement Project (CS-23) is to evaluate the constructed project features to identify any deficiencies and prepare a report detailing the condition of project features and recommended corrective actions needed. Should it be determined that corrective actions are needed, CPRA shall provide, in the report, a detailed cost estimate for engineering, design, supervision, inspection, and construction contingencies, and an assessment of the urgency of such repairs (O&M Plan, 2002). The annual inspection report also contains a summary of maintenance activities which were completed since project completion and an estimated projected budget for the upcoming three (3) years for operation, maintenance and rehabilitation. The three (3) year projected operation and maintenance budget is shown in Appendix B. A summary of past operation and maintenance projects completed since completion of the Sabine Refuge Protection Project are outlined in Section IV.

An inspection of the Sabine Refuge Structure Replacement Project (CS-23) was held on November 12, 2014 under cloudy skies and cold temperatures. In attendance were Dion Broussard of CPRA, Darryl Clark of USFWS, and Brandon Samson of NRCS for other inspections. The inspection began at the Hog Island Gully Structure at approximately 11:00 am and ended at the West Cove Structure at 12:00 pm. (CPRA. 2014).

The field inspection included an inspection of all three project sites. Staff gauge readings and existing temporary benchmarks where available were used to determine approximate elevations of water, rock embankments, concrete structures and other project features. Photographs were taken (see Appendix A) and Field Inspection notes were completed in the field to record measurements and deficiencies (see Appendix C).

b. Inspection Results

Structure A - Hog Island Gully Canal

The structure is in fully operational condition as a result of the 2011 maintenance event. The conversion from single to dual stems appears to have helped with the operation of the gates. (Photos: Appendix A, Photos 1 - 2)

Structure B - Headquarters' Canal

The structure is in fully operational condition, with the exception of structure No. 3 gear box repair, as a result of the 2011 maintenance event. (Photos: Appendix A, Photos 3-4).

Structure C - West Cove Canal

During the 2014 inspection, the structure was not operational. However, minor maintenance has been performed and the structure is fully operational at this time. The conversion from single to dual stems appears to have helped with the operation of the gates. (Photos: Appendix A, Photos 5-6).

c. Maintenance Recommendations

i. Immediate/ Emergency Repairs
No repairs are required at this time.

ii. Programmatic/ Routine Repairs
No Repairs are required at this time.

d. Maintenance History

General Maintenance: Below is a summary of completed maintenance projects and operation tasks performed since February 2000, the construction completion date of Sabine Refuge Structure Replacement Project (CS-23).

- **June, 2005 – F. Miller & Sons, Inc.**
  A maintenance event was performed to correct the following:

  1. Install operating nut in gate 6A, Hog Island Gully.
  2. Free gate 6b that is jammed, Hog Island Gully.
  3. Replace operation nut in gate 3A, West Cove.
  4. Replace batteries in all Rotork Actuators and re-calibrate.

Construction (Item Nos. 1, 2 & 3):	$ 7,800.00
Construction (Item No. 4):	$ 5,416.45
PROJECT TOTAL:	**$13,216.45**

- **June, 2006 – U.S. Fence & Gate, Inc.**
  A maintenance event was performed to correct the following:

  Remove existing fence and posts damaged by Hurricane RITA at both Hog Island Gully and West Cove Structures and replace with new chain link fence material and new posts.

Construction Cost:	$8,360.00
Engineering Design and Construction Oversight:	In-House
PROJECT TOTAL:	**$8,360.00**

- **June – October, 2008 – Electrical Repairs by USFWS via Tennessee Valley Authority (TVA)**

  The TVA, under contract with USFWS and post-Rita funds, replaced storm-damaged wiring, installed true 3-Phase power from Jeff Davis Electric Co-Op transformers at Highway 27 to the structures, relocated all controls to the top platform, removed the rotary phase converter, and wired the actuators using an on-off control switch.

  PROJECT TOTAL: $232,979

- **2009 - Lonnie Harper & Associates - E&D of Repairs and Modifications to Structures**

  Post-Rita FEMA funding was used for preparation of plans and specifications for structure repair and modifications.

  FEMA ALLOWANCE: $144, 185

- **September, 2009 – A-1 American Fence, Inc.**

  A maintenance event was performed to correct the following:

  Remove existing fence and posts damaged by Hurricane Ike at both Hog Island Gully and West Cove Structures and replace with new chain link fence material and new posts.

Construction Cost:	$ 5,500.00
Engineering Design and Construction Oversight:	$18,566.93
PROJECT TOTAL:	**$24,066.93**

- **April, 2011 – L.S. Womack, Inc.**

  A maintenance event was performed to correct the following:

  1. Dismantling of Hog Island Gully and West Cove structures.
  2. Cleaning and performing modifications to all gates at both Hog Island Gully and West Cove structures.
  3. Refurbishing gear drives and actuators for gates where 3” stems were to be replaced with 2.5” stems.
  4. Refurbishing the gear drive and actuator at Headquarters.
  5. Structural modifications to the 7’-6” gates at both Hog Island Gully and West Cove structures included modifying the stem attachments to accommodate a dual stem configuration.

6. Removal of the leak proof gasket, modify structural steel platforms at Hog Island Gully and West Cove structures to accompany new gate connection and stems.
7. Reworking of all electrical connections to provide complete operation of all three structures.
8. During construction, it was determined that the gates required structural repairs to maintain the integrity of the gates. 193 stitch welds were performed on 22 gates, to repair broken welds and strengthen the integrity of the gates.

Construction Cost:	$1,288,934.82
Engineering Design and Construction Oversight:	$ 64,077.11
PROJECT TOTAL:	**$1,353,011.93**

III. Operation Activity

a. Operation Plan

Normal Operation: The structures are operated based on salinity and water level data. The targeted levels are defined in the permitted Operational Plan (See Appendix E). Water exchange will be provided through open bays having approximately the same cross-sectional area as that provided by the old structures' fully open gates [182 ft^2 total area]. The slide/sluice gates of the flapgated bays may be adjusted by the refuge manager at his discretions, except for the middle Headquarters' Canal Structure culvert (HQ2) which will remain 50 percent open. All flapgates will remain down in the operating position, except for HQ2 in which the flapgate will be locked closed to serve as the sluice gate.

Hog Island Gully Canal-Structure A: Normal management of this structure would provide a cross-sectional area of 112 ft^2 compared with 93.5 ft^2 of gated opening in the old structure.

HG1	HG1	HG2	HG2	HG3	HG4	HG5	HG6	HG6
Slide Gates	Flap Gate	Slide Gates	Flap Gate	Slide Gates	Slide Gates	Slide Gates	Slide Gates	Flap Gate
MD	Down	MD	Down	-7'	-7'	-7'	MD	Down

MD=Manger's discretion

Headquarters' Canal – Structure B. Normal management provides a cross-sectional area of approximately 10 ft^2 compared with 0 to 12.6 ft^2 of gated opening maintained through operation of the old structure.

HQ1 Sluice	HQ2 Sluice	HQ3 Sluice
Sluice Open	Sluice ½ Open	Sluice Open

West Cove Canal - Structure C. Normal management would provide a cross-sectional area of 60 ft^2 compared to 59.5 ft^2 of gated opening in the old structure.

WC1 [DC1]Slide Gage	WC1 Flap Gate	WC2 Slide Gate	WC3 Slide Gate	WC4 Slide Gate	WC5 Slide Gate	WC5 Flap Gate
MD	Down	+2'	-7'	+2'	MD	Down

Deviations from normal operation will be short-term and conducted for the reason identified below.

Increased Exchange Operation:

Additional gates may be temporarily opened to the degree necessary as determined by the refuge manager for any of the following reasons.

1) To discharge excess water
2) To facilitate inflow of freshwater, or water of lower salinity
3) To enhance ingress and egress of estuarine-dependent fishes and shellfishes
4) To discharge anoxic waters

High Water Provisions: When water levels in interior marshes exceed four inches above average marsh level for four days or more, the discharge capacity of structures A, B, and or C will be increased with flap gates or by raising slide gates or sluice gates to permit outflows. Normal operation will be restored when the water conditions have receded.

Storm provisions: Prior to a storm's approach, flapgated bays may be readied in advance for later discharge of excess water by raising and thereby opening the sluice gates of those bays equipped with flapgates. Prior to a storm's approach, refuge personnel may restrict or close non-flapgated bays to reduce exposure or interior marshes to saltwater tidal surges. Following a storm, normal or restricted water exchange operations shall be resumed on non-flapgated bays in accordance with the established salinity and water level provisions and criteria. In an attempt to reduce the exposure of interior marshes to saltwater because of tropical depression tidal surges, the gates will be closed precluding any surges. Following the inundation of high tides and rainfall, the gates will be opened to alleviate interior marsh flooding.

Monitoring Activities: Baseline salinity and water level monitoring, using continuous recorders, began in April 1998 using the standard Coastal Wetlands, Planning, Protection, and Restoration Act monitoring protocol (Steyer et. al 1995, revised 2000). The Coastal Protection and Restoration Authority (CPRA) have deployed six continuous monitoring recorders (sondes) within the project area. The U.S. Fish and Wildlife Service (USFWS) collected salinity, water temperature and specific conductivity parameters at area stations approximately every two weeks until structure operations began after 2001. Due to the impending installation of Coastwide Reference Monitoring System (CRMS) stations (Figure 3), data collection at two of the continuous recorder monitoring stations (CS23-01 and CS23-02) was discontinued in May 2004. The remaining continuous recorder monitoring stations (CS23-BS-T, CS23-BC-T, CS23-HIG-T, CS23-WC-T and CS23-BL-T) are setup with telemetry capabilities and will be used for data collection and to aid in structure operations.

b. Actual Operations

In accordance with the operation schedule outlined in the Operation and Maintenance Plan and USACE Permit, structures are operated by USFWS personnel. However, the Hog Island Gully and West Cove structures were not fully operational until December 2011 due to electrical service issues, operating nut failures, Hurricanes Rita 2005 and Ike 2008. Copies of the actual operation reports may be obtained from the USFWS, Sabine National Wildlife Refuge Office located at 3000 Holly Beach Hwy, Hackberry, LA 70645; (*337-762-3816* or *sabine@fws.gov*).

IV. Monitoring Activity

Pursuant to a CWPPRA Task Force decision on August 14, 2003 to adopt the Coastwide Reference Monitoring System-*Wetlands* (CRMS-*Wetlands*) for CWPPRA, updates were made to the CS-23 Monitoring Plan to merge it with CRMS-*Wetlands* and provide more useful information for modeling efforts and future project planning while maintaining the monitoring mandates of CWPPRA. Data from 12 CRMS sites and the CS-20 reference station (CS20-15R) were used to determine project effectiveness in this report.

a. Monitoring Goals:

The objective of the Hog Island Gully, West Cove & Headquarters Canal Structure Replacement Project is to increase the cross-sectional area and operation ability of the projects water control structure features to improve hydrologic conditions that control high saline waters, increase water discharge capacities, and maintain emergent vegetation.

The following goals will contribute to the evaluation of the above objectives:

1. Reduce the occurrence of salinities that exceed target levels during the growing and non-growing seasons at stations CS23-02, CS23-03, CS23-05 and CS02-05. Target levels range from 2 – 8 ppt during the growing season and 3 – 10 ppt during the non-growing season.

2. Minimize frequency and duration of marsh flooding events.

3. Maintain existing intermediate and brackish vegetation communities.

4. Increase occurrence of submerged aquatic vegetation (SAV).

b. Monitoring Elements

Aerial Photography

To document land and water acreage and land loss rates in project and reference area, near-vertical color infrared aerial photography (1:12,000 scale) was obtained pre-construction in 2000. The original photography was checked for flight accuracy, color correctness, and clarity and was subsequently archived. Aerial photography was scanned, mosaicked, and georectified by USGS/NWRC personnel according to standard operating procedures (Steyer et al. 1995, revised 2000). Based on the CRMS review, aerial photography originally scheduled for 2004, 2009 and 2018 was eliminated. The CRMS spatial viewer provides historic data for land water quantification from 1932 to 2010 and at irregular intervals as data becomes available. The year analyzed for land water quantities through the CRMS viewer was 2010. The data provided by this tool is at a large spatial scale and is designed to show trends in land change, not exact acreages.

Salinity

CRMS data from 11 sites, eight inside the project area (CRMS0635, 638, 641, 651, 677, 1205, 1858, and 2334) and three outside the project (CRMS0672, 685 and 687), along with the CS20-15R reference site were utilized to assess salinity goals (Figure 1). The sites chosen were all open-water sonde setups, and not marsh well setups. Salinity was monitored hourly from 1/1/2008 -12/31/2012 (post-construction) and will be used to identify the amount of time that salinities exceed target levels within the project area.

Water Level

CRMS data from 11 sites, eight inside the project area (CRMS0635, 638, 641, 651, 677, 1205, 1858, and 2334) and three outside the project (CRMS0672, 685 and 687), along with the CS20-15R reference site were utilized to assess water variability goals (Figure 1). The sites chosen were all open-water sonde setups, and not marsh well setups. Water level was monitored hourly from 1/1/2008 -12/31/2012 (post-construction) and will be used to identify annual duration and frequency of flooding. A staff gauge has been surveyed adjacent to each CRMS site to correlate water levels to a known datum. Marsh elevations are correlated to the staff gauges and will be used in determining marsh flooding events.

Vegetation

CRMS data from 14 sites, eleven inside the project area (CRMS0635, 638, 639, 641, 642, 647, 651, 677, 1205, 1858, and 2334) and three reference sites (CRMS0672, 685, and 687) located outside the project area, were utilized to assess percent cover and species composition by salinity. In order to assess the project goal of maintaining intermediate and brackish vegetation communities, vegetation data was assigned a salinity category based on what marsh type the individual species were most commonly found, e.g. fresh, intermediate, brackish, and saline, along with transitional classes such as fresh-intermediate, intermediate-brackish, and brackish-saline using the Visser classifications (Sasser and Visser 2008). This approach examines marsh type transitions and trends as the process of changing classifications takes place.

Submerged Aquatic Vegetation

To determine the occurrence of SAV within the project and reference area, eight ponds were randomly sampled for presence or absence of SAV using the modified rake method (Nyman and Chabreck 1996). Five ponds are located in the project area and three in the reference area. Transect lines were set up within each pond and a minimum of 25 samples were taken along each transect line, not to exceed 100 samples per line. Depending on pond configuration and wind direction, the number of transect lines within each pond varies. SAV was monitored in 1999 (pre-construction) and in July 2004, June 2009 and June 2014 post-construction. Future SAV data are scheduled to be collected in 2018.

CRMS Supplemental

In addition to the project specific monitoring elements listed above, a variety of other data is collected at CRMS-*Wetlands* stations which can be used as supporting or contextual information. Data types collected at CRMS sites include hydrologic from continuous recorder and vegetative data which were both used to address monitoring goals of the project (Folse et al. 2012). Other parameters such as physical soil characteristics, discrete porewater, surface elevation, and land:

water analysis of 1 km^2 area encompassing the station is given for an environmental overview. For this report, eight CRMS sites were used to assess hydrologic parameters and eleven CRMS sites were used to assess vegetation parameters within the project area. Three CRMS sites outside along with the CS20-15R reference station were used as reference stations in a traditional project versus reference manner. Data collected from the CRMS network with a sufficient amount of time to develop valid trends was used to develop data indices that can be used to indicate project performance.

Soil interstitial (porewater) salinity data were collected monthly from 10 and 30 cm depths at eleven CRMS sites; eight within the project and three within the reference areas. Monthly porewater salinity data were averaged into yearly means to compare differences within the project and reference areas for years 2006 – 2012. Vegetation plot porewater was excluded from this data set.

Soil cores were collected one time (within a year of site establishment) to describe soil properties (bulk density and percent organic matter). Three, 4" diameter cores were collected to a depth of 24 cm and divided into 6, 4-cm sections at the site. The soil was processed by the Department of Agronomy and Environmental Management at Louisiana State University.

Soil surface elevation change utilizing a combination of sediment elevation tables (RSET) and vertical accretion from feldspar horizon markers are being measured twice per year at each site. This data will be used to describe general components of elevation change and establish accretion and subsidence rates.

c. Preliminary Monitoring Results and Discussion

i. Aerial Photography

Land/water analysis was acquired in November 2000 (Figure 3) and in 2010 using the CRMS assessment tool. In 2000 the project area had a ratio of 67.5% land (28,146.8 ac) to 32.5% water (13,572.1 ac) to 68.0% land (28,375.1 ac) and 31.9% (13,330.8 ac) water in 2010. The project area had a net increase in land of 0.5% (208.6 ac). In 2000 the reference area had a ratio of 57.9% (1,695.5 ac) land to 42.1% (1,233.5 ac) water (figures 3 and 4). CRMS assessment tool does not quantify land/water within the reference area. There is no additional aerial photography planned for the reference area of the project.

Project scale percent land/water analysis was performed from 1985 to 2010 using the CRMS assessment tool for the CS-23 project area. The land/water assessment showed that the land increased from 63.8% (26,601.3 ac) to 72.0% (30,049.9 ac) between 1985 and 1990. From 1990 to 2004 the percent land remained stable with the percent land averaging 73.1% (30,493.6 ac). Hurricanes Rita in 2005 and Ike in 2008 show the percent land declining to 66.1% (27,562.3 ac) in 2009. In 2010 a slight marsh recovery trend is shown with percent land increasing to 68.0% (28,375.1ac) (Figure 4).

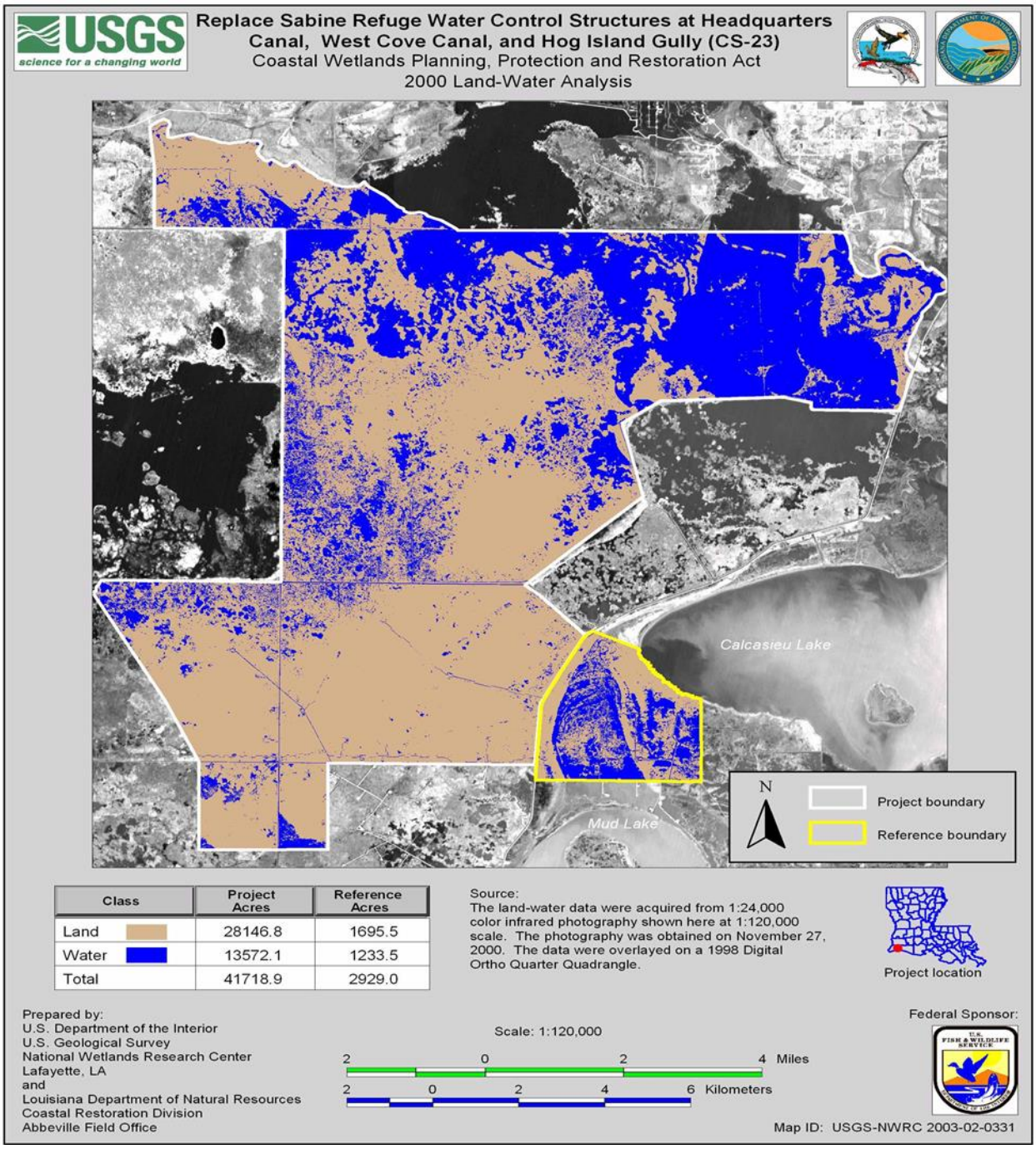


Figure 3. Land/water analysis of the Sabine Structure Replacement (CS-23) for the project and reference areas from photography obtained November 27, 2000.

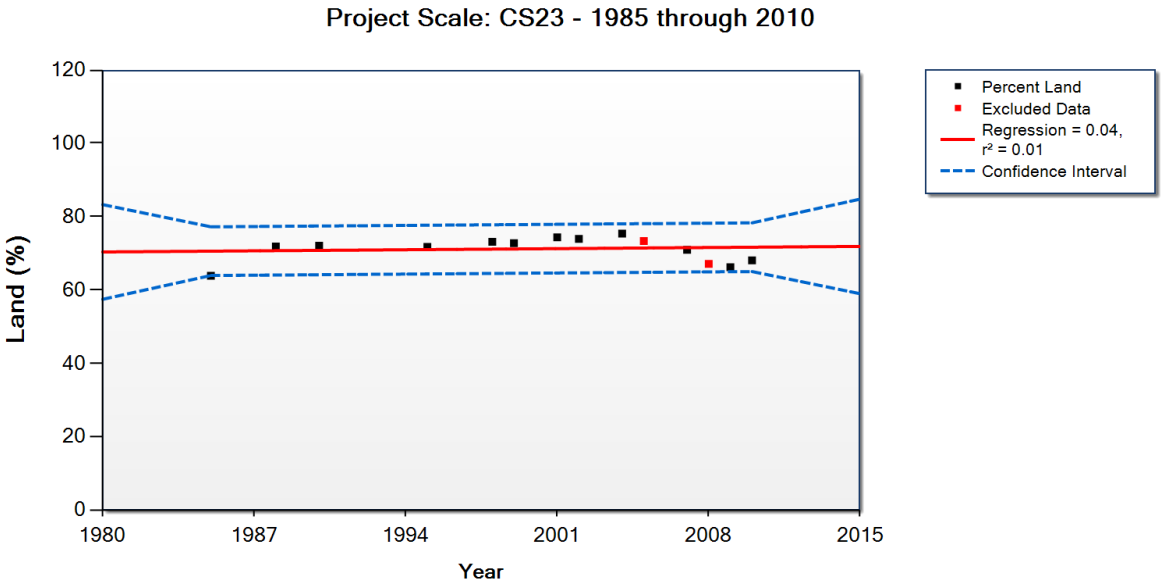


Figure 4. Project scale percent land/water using the CRMS assessment tool for years 1985 to 2010 within the CS-23 project area.

ii. Salinity

Salinity data was collected hourly at eleven CRMS stations; eight are CRMS sites located within the CS-23 project area and three are CRMS sites within the reference areas along with the CS20-15R reference station (Figure 1). Weekly mean salinity was calculated from the daily means of hourly data from 2008 to 2015. The data reveals that the project area salinities are lower than the reference area salinities when the structures became fully functional except in January-February 2012 when salinities were equal to the reference salinities for a short period of time (Figure 5). With the ability to fully operate the structures in 2012, the prevention of saltwater into the project area is evident as salinities remained below reference area salinities from 2012 to 2015 (Figure 5).

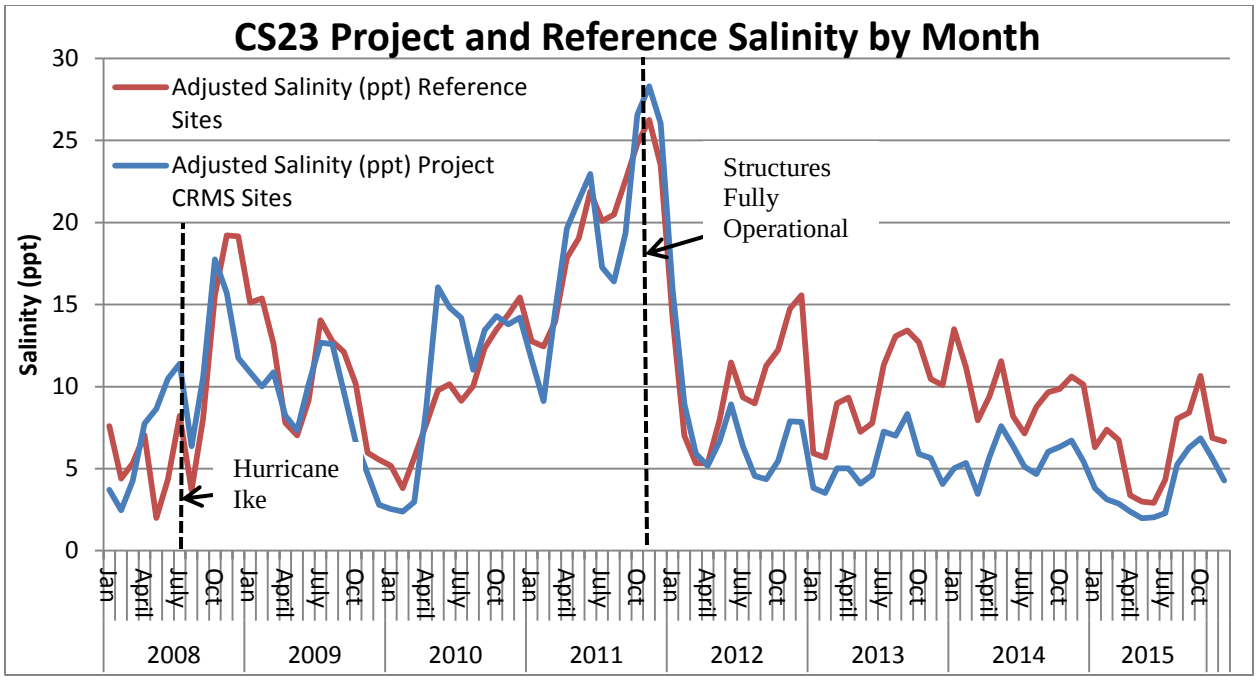


Figure 5. Weekly mean salinities from 2008-2015 at thirteen CRMS sites within the CS-23 project (n=8) and reference (n=5) areas.

The project goal was to maintain salinity between 2 and 8 ppt during the growing season (March-August) and between 3 and 10 ppt during the non-growing season (September – February). The percent time the salinity was in target was calculated using hourly salinity (ppt) data from 01/01/08 – 12/31/15.

The structures were not fully functional until December 2011. During that time, salinity wasn't fully controlled. From 2012 to 2015 It is evident that the salinities, during the growing and non-growing season were within the target range much more often (Figure 6). Between 2013 and 2015 the salinities were within or below the target range 100% of the time. The reference area was above the target range 71% of the time during the growing season between 2009 and 2014 except in 2008 and 2015 which had abundant rainfall (Figure 6).

The ability to fully operate the structures during the growing season is critical in maintaining a salinity and water level balance for vegetation to regenerate. The growing season is heavily influenced by south winds, higher tides and elevated saline waters that can now be controlled by proper structure operations. Now that the structures are fully operational, salinities are on target more often.

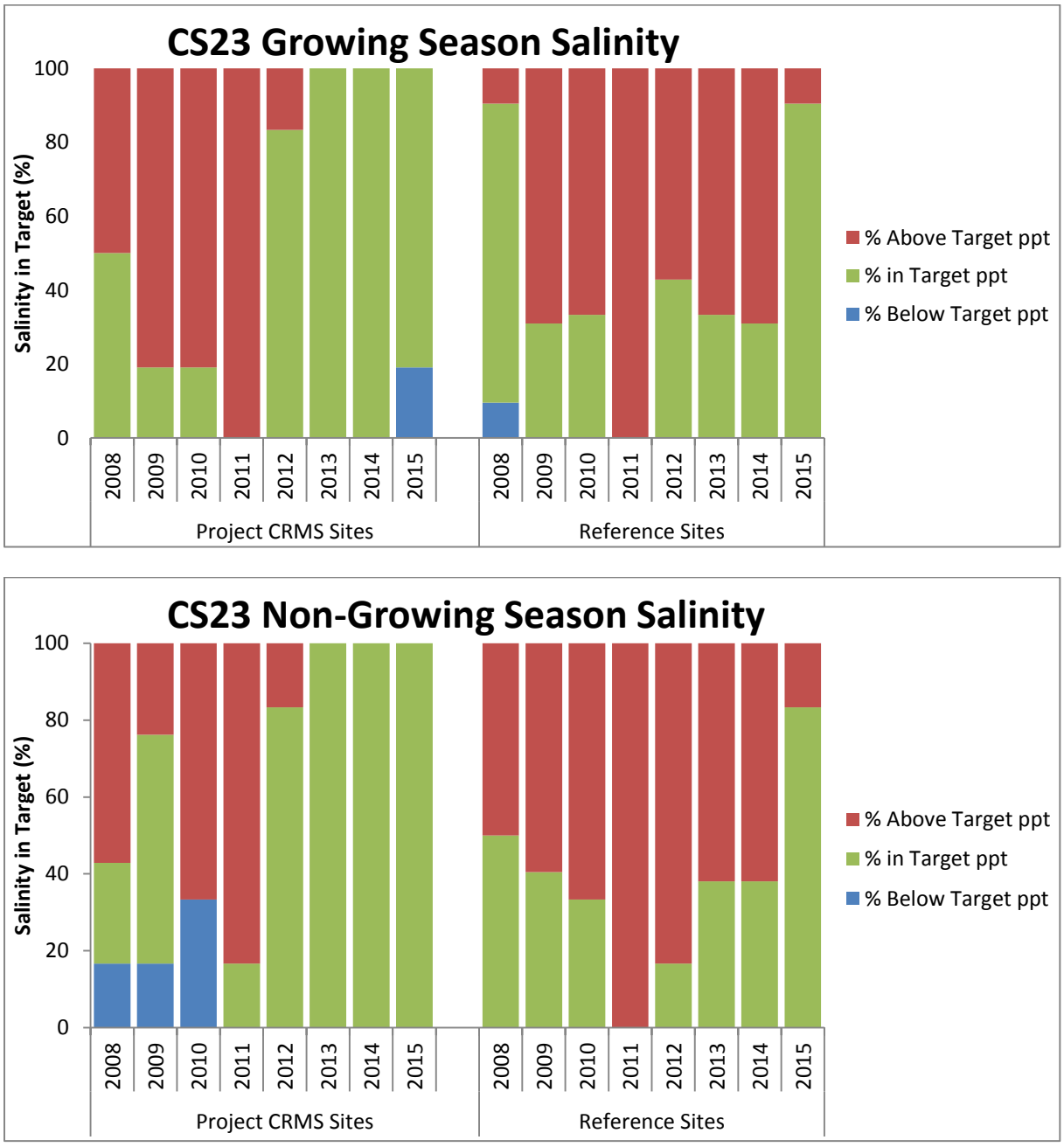


Figure 6. Percentage of the year that weekly average salinity levels were below target, in target, and above target range for CRMS sites within the project (n=8) and reference (n=4) areas for years 2008 – 2015.

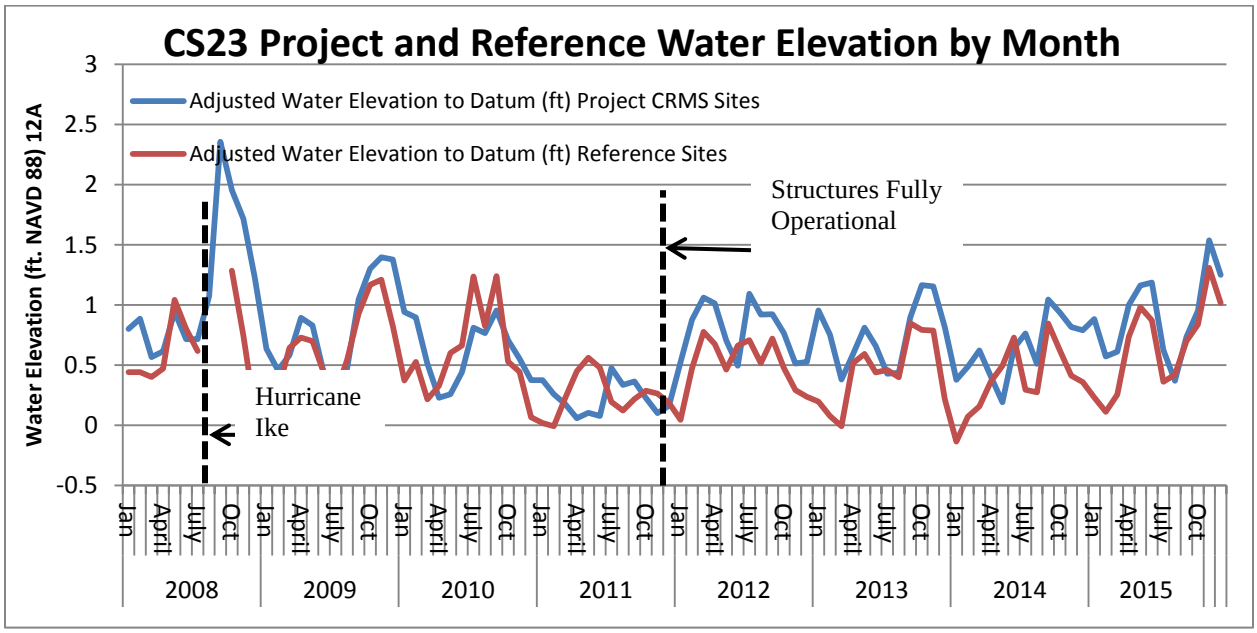
iii. Water Level

Water level data was collected hourly at eleven CRMS stations; eight are CRMS sites located within the CS-23 project area and three are CRMS sites within the reference areas along with the CS20-15R station (Figure 1).

Monthly means of adjusted water level (geoid 12A) relative to the marsh surface was calculated from daily means of CRMS hourly data from 2008-2015 (Figure 7). The highest water levels occurred during July 2008 when average water levels reached 2.39 ft in the project area following the passage of Hurricane Ike. From 2009 to 2011 water levels were varying with levels being higher at times within the project sites when compared to the reference sites. The lowest water levels of 0.55 ft. (NAVD) were recorded in January 2011. After December 2011when structures became fully operational water levels had less variance but were still overall higher within the project area (Figure 7). The ability of water to exit from within the project area on normal operations is restricted due to the structures limited cross sectional area. When outside salinities are above target range the structures are operated for moon phase ingress and egress thus further limiting the ability for drainage.

The structures were not functioning properly until December 2011. During that time, water level wasn't fully controlled. Water levels at sites in the reference area during the growing and non-growing seasons were on target more often than the project sites from 2008 to 2015 (Figure 8).

Water levels were above target more often in 2012 during the growing season (67% of the time) as compared to the non-growing season (29% of the time) which suggests that the structures being operational did not help at times. However, 2012 was a very wet year. The ability to fully operate the structures during the growing season is critical in maintaining a salinity and water level balance for vegetation to regenerate. The growing season is heavily influenced by south winds, higher tides and elevated water levels that limit the times water can flow out of the system causing above target water levels to occur more often within the project area. The non-growing season is influenced by frontal passages, north winds which lower outside water levels which allow for increased openings and greater opportunities to maintain water levels within the target range.



[BW2]

Figure 7. Monthly means of adjusted water elevations to datum for CRMS sites located within the project (n=8) and reference (n=5) areas for years 2008 to 2015.

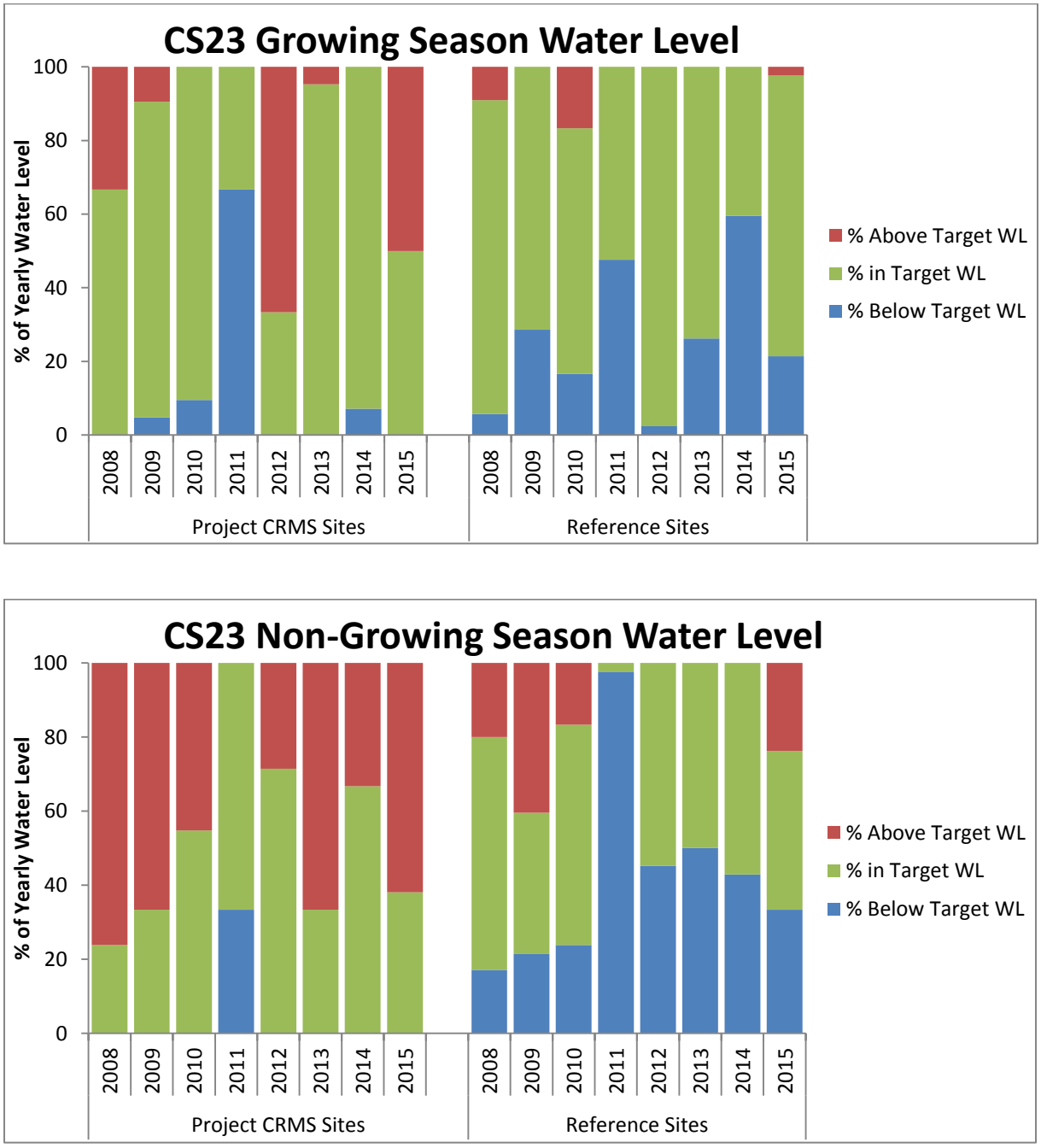


Figure 8. Percent of time water levels were within the target range (2" AME to 6" BME) during the growing and non-growing seasons at CRMS sites within the project (n=8) and reference (n=4) areas.

iv. Vegetation

To determine if the marsh was maintaining an intermediate to brackish vegetation community 11 CRMS project sites and 3 CRMS reference sites were analyzed using percent cover by vegetation salinity type. The inter-brackish vegetation communities within the project area have increased in percent cover from 2006 to 2015. Between 2006 and 2015 the project inter-brackish percent cover increased from 22.8% to 58.9% (Figure 9). The fresh to inter-brackish percent cover has been stable since 2010 with percent cover averaging 88.0%. The project area has maintained an intermediate to inter-brackish vegetation community as it recovered from prior hurricane damage. The reference area has maintained a saltier cohort of herbaceous species making up the vegetation communities with most ranging from brackish to saline, as fresh and fresh intermediate species are completely removed from the landscape by 2011 (Figure 9).

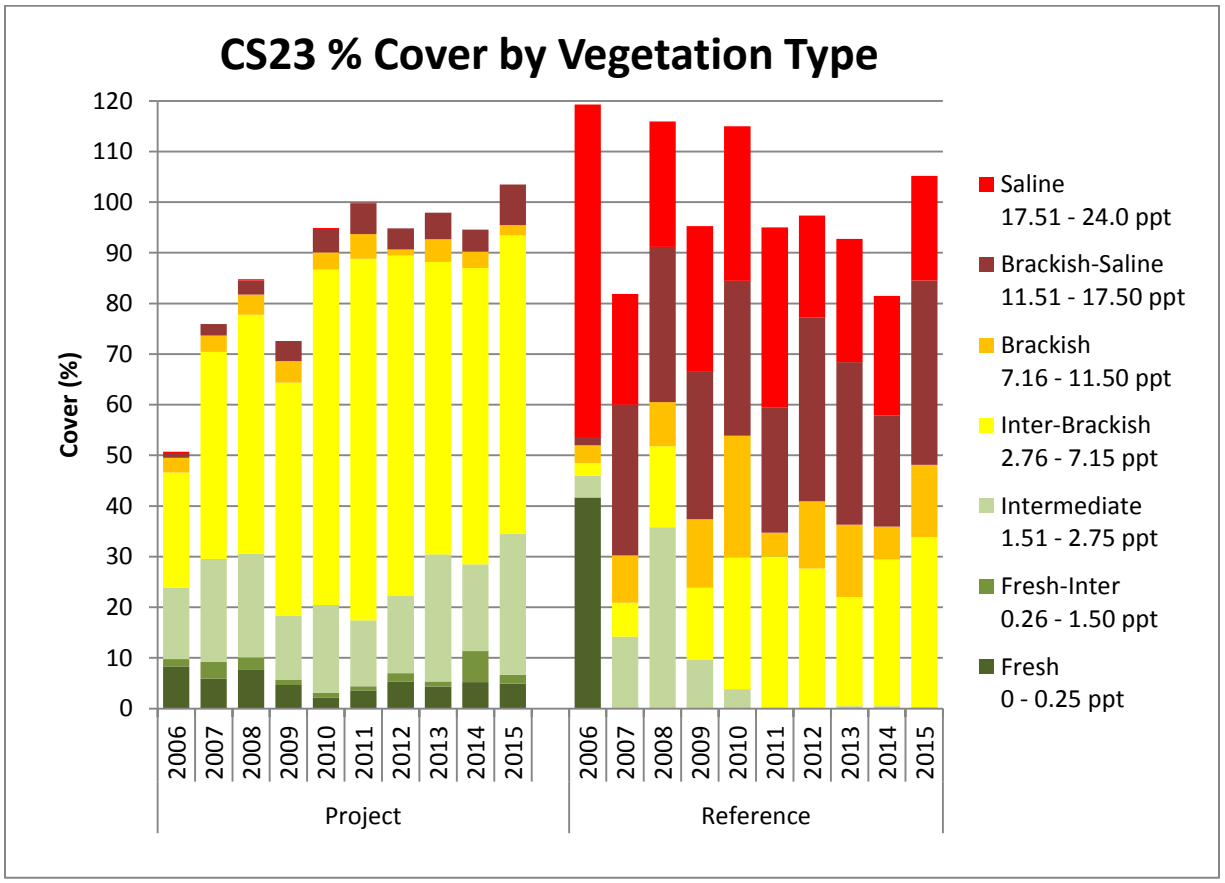
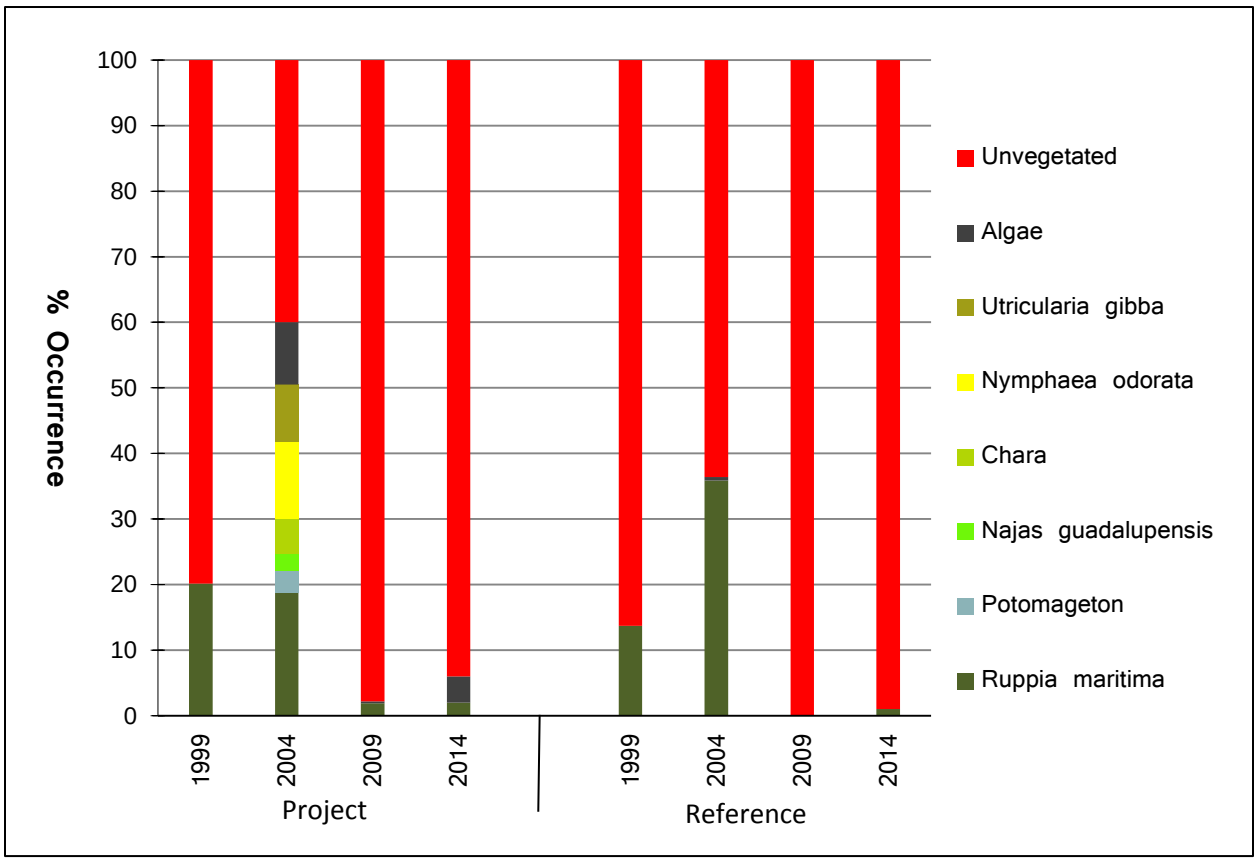


Figure 9. Percent cover by vegetation type within the project CRMS sites (n=11) and reference CRMS sites (n=3).

v. Submerged Aquatic Vegetation

SAV was collected in 1999 pre-construction and in 2004, 2009 and 2014 post-construction. Percent occurrence by species was calculated on all SAV transects in the project and reference areas (Figure 10). *Ruppia maritima* was present in the project area for all sampling periods although it was minimal in 2009 and 2014 with only 2 percent occurrence. The reference area had a presence of *Ruppia* in the 1999 (14%) and 2004 (36%) but it had disappeared by 2009. In 2004 the project area experienced an abundance of additional species, *Potomageton pectinatus, Najas guadalupensis, Chara, Nymphaea odorata, Utricularia gibba* and *algae* but these species were not present within the reference area. The dependence of water clarity, water temperature, water depth and salinity play a major role in the SAV occurrences. When conditions are favorable for SAV occurrences, an abundance of SAV species can occur as can be seen in the 2004 data collection period.



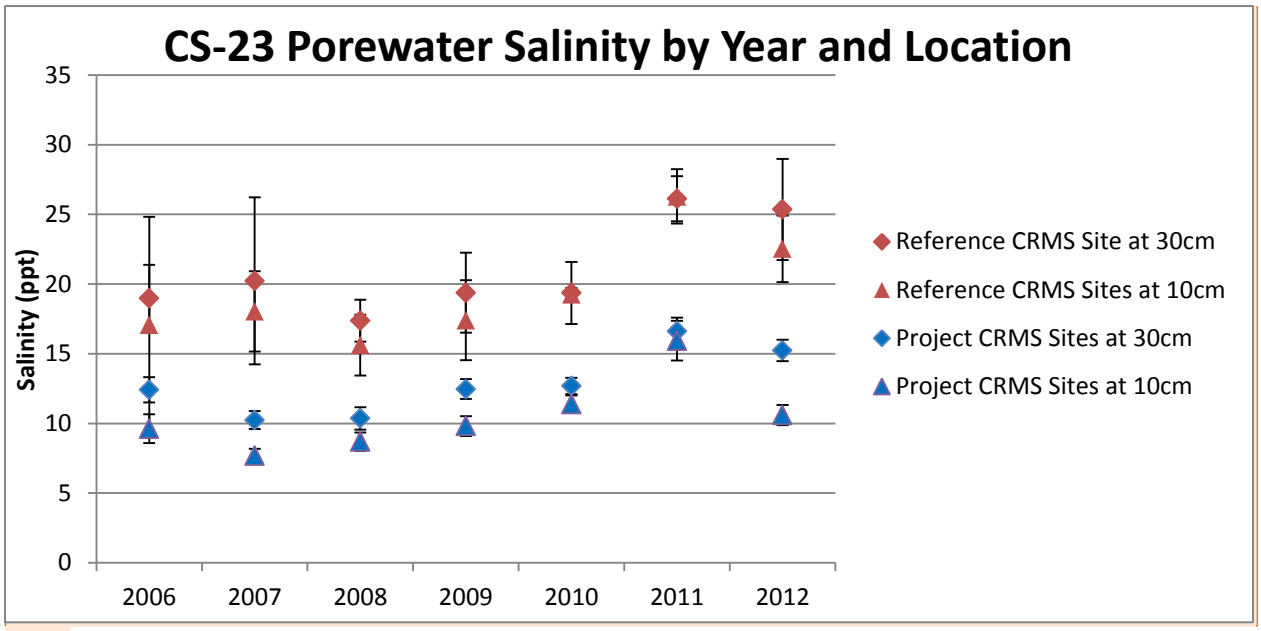
[LAS3]**Figure 10.** Percent occurrences of SAV within the project and reference area for the 1999, 2004, 2009 and 2014 sampling periods.

vi. CRMS Supplemental:

Soil Porewater

Soil interstitial (porewater) salinity data were collected from 10 and 30 cm depths at 8 CRMS sites within the project and 3 sites within the reference area (Figure 11). Monthly porewater data were averaged into yearly means for the project and reference areas for years 2006 – 2012. The

project area porewater salinities are much lower than the reference areas at the 10 and 30 cm depths for all years. An increase in soil salinities was associated with the severe 2011 drought, but the increase occurred equally within each of the areas. Project porewater salinities ranged from 8 – 16 ppt which is within the brackish range of vegetative species occurring in the project area. The reference area porewater salinities of 16 – 26 ppt fall within saline range and is indicative of the vegetation species occurring within the reference area.



[LAS4]

Figure 11. Yearly means of CRMS porewater salinity data within the project (n=8) and reference (n=3) areas collected at 10 and 30 cm (mean ± standard error).

Marsh Elevation Change

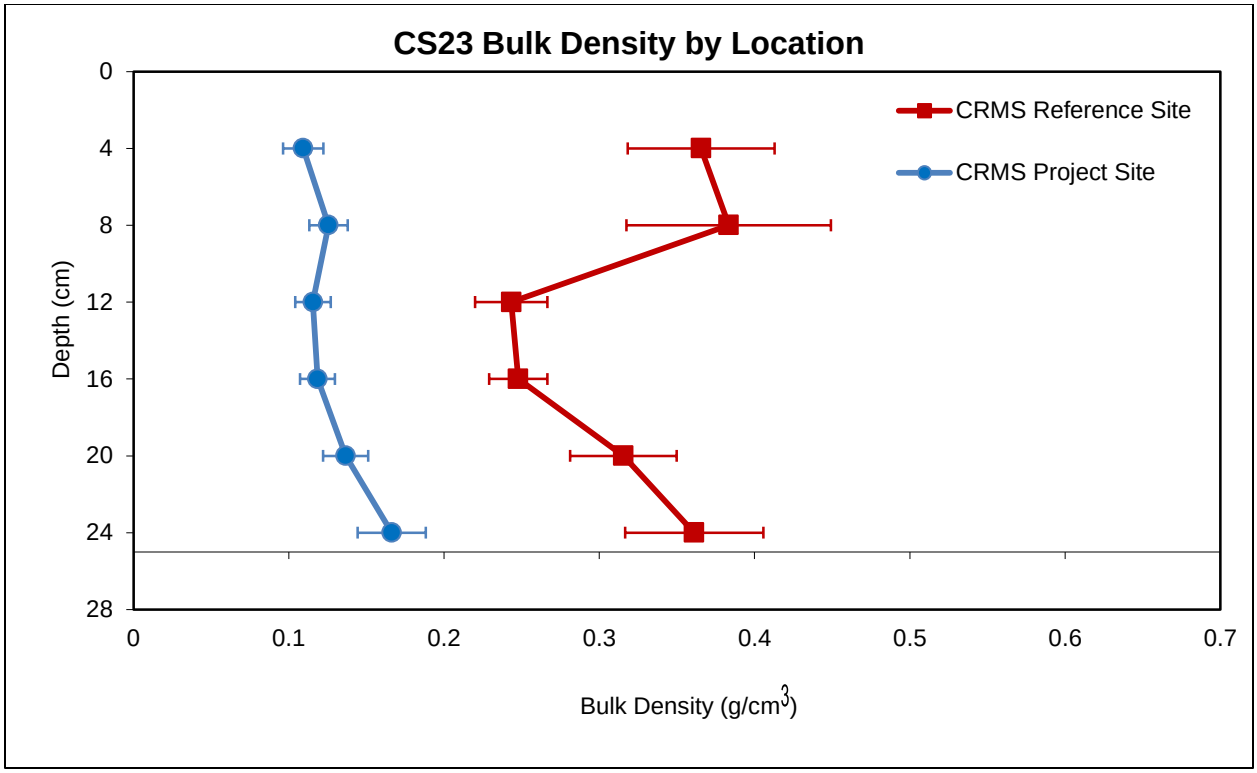
Elevation change and accretion data were collected at eight CRMS sites within the project area and three sites within the reference area (Table 1). The project area shows an average elevation change rate of -0.42 cm/yr as compared to the reference sites which show an average change rate of 0.57 cm/yr. However the average vertical accretion rates are higher within the project area (0.71 cm/yr) than in the reference area (0.07 cm/yr). The land loss within the project area could be linked to the effects of Hurricanes Rita (2005) and Hurricane Ike (2008) along with the project's location to Calcasieu Lake. Natural sedimentation from the turbid Calcasieu Lake waters into the project area has been limited in an effort to control salinities and marsh flooding through the use of man-made structures. The reference area stations which are located along the rim of Calcasieu Lake experience natural sedimentation processes from tidal cycles and high water levels. The typical cycle in these locations is accretion building up along the lake rim contiguous to the ship channel as interior areas are cut off and undergo sedimentation starvation.

Station ID	CRMS Site	Elevation Change cm/yr	Vertical Accretion cm/yr	Shallow subsidence cm/yr	RSLR cm/yr	Elevation Change Rate cm/yr
Project	635	-0.28	0.08	0.37	0.57	0.85 < projected RSLR
Project	638	-0.57	0.61	1.18	0.57	1.14 < projected RSLR
Project	641	-0.6	0.84	1.43	0.57	1.16 < projected RSLR
Project	651	-0.35	1.6	1.94	0.57	0.91 < projected RSLR
Project	677	0.01	0.84	0.83	0.57	0.55 < projected RSLR
Project	1205	-0.97	0.14	1.11	0.57	1.54 < projected RSLR
Project	1858	-0.01	1.72	1.73	0.57	0.58 < projected RSLR
Project	2334	-0.53	0.74	1.27	0.57	1.09 < projected RSLR
Average Project		-0.42	0.71	1.13	0.57	
Reference	672	0.58	-0.22	-0.8	0.57	0.01 > projected RSLR
Reference	685	0.43	0.41	-0.02	0.57	0.13 < projected RSLR
Reference	687	0.69	0.01	-0.68	0.57	0.13 > projected RSLR
Average Reference		0.57	0.07	-0.50	0.57	

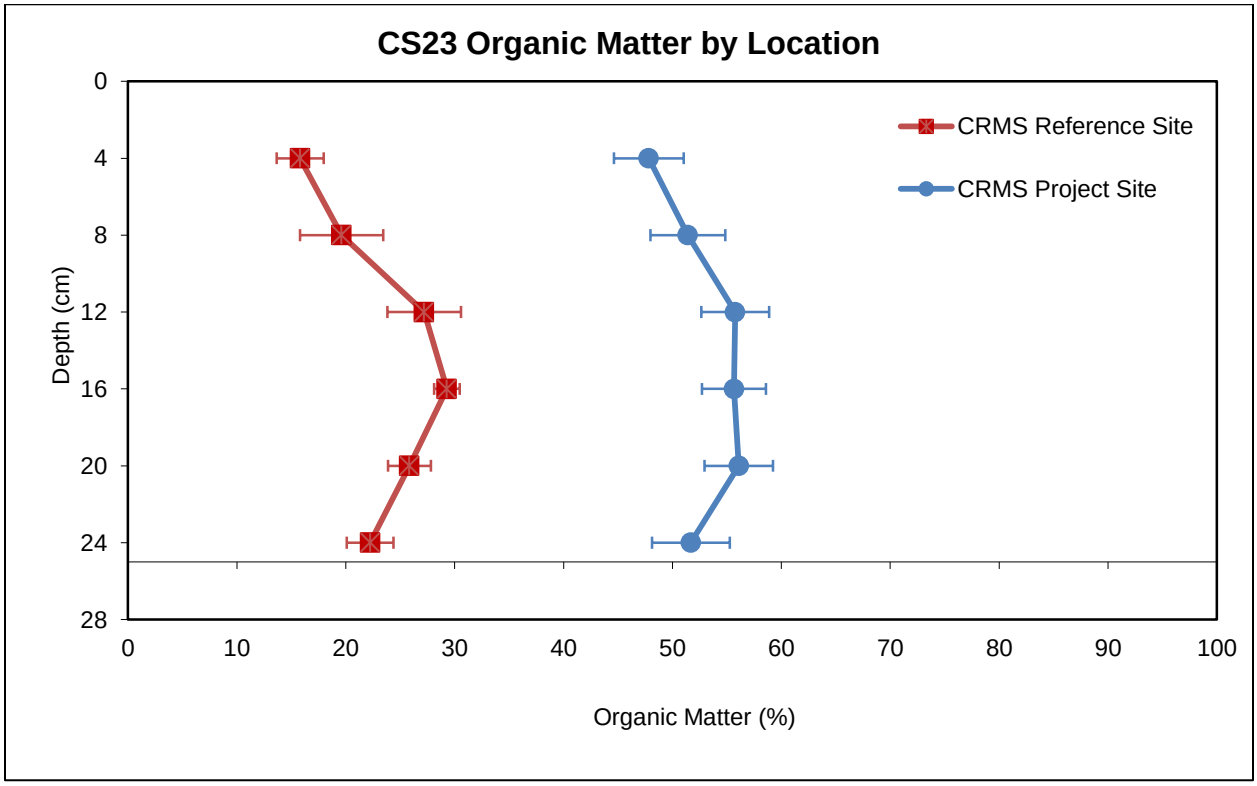
Table 1. Elevation change (cm/yr) and subsidence (cm/yr) rates of CRMS stations within the CS-23 project (n=8) and reference (n=3) areas.

Soil Bulk Properties

Soil samples were collected in 2007 at 8 CRMS sites within the project area and 3 CRMS sites within the reference areas. Figures for mean bulk density and organic matter are presented in figures 12a and 12b. Bulk density was higher in the reference sites (n=3) than the project sites (n=8) throughout all depths (figure 12a). The reference CRMS sites show a decrease in bulk density from 12-16 cm which can likely be attributed to organic deposition occurring at some point in time. Percent organic content was higher in the project sites (n=8) than the reference sites (n=3) throughout all depth profiles (Figure 12b). This is likely due to the influence of the structures ability to deter natural tidal cycles and to reduce the ability of sedimentation to occur within the project area.



[LAS5]



Figures 12a and 12b. Bulk density and % organic matter of CRMS sites with available data for soil bulk properties among project and reference sites.

V. Conclusions

a. Project Effectiveness

After Post-construction there were operational issues at the Hog Island Gully and West Cove structures which prevented the structures from being fully operated as designed. The operations were disrupted mainly due to electrical actuator problems and gate misalignment causing failure of the stem operating nut. In addition, the two hurricanes, Rita 2005 and Ike 2008, exacerbated damage to the structures. After various post-construction maintenance events as outlined in this report and an extensive refurbishment in April 2011, the Hog Island Gully and West Cove structures have been repaired and are fully operational. Data collected after April 2011 shows the projects effectiveness at curtailing saltwater into the project area, but it also shows that the limited opportunities for drainage have had an effect on increased water levels within the project area compared to the reference area. The control structures are fully operational at this time. The USFWS now operates structures monthly to check for problems. The CPRA is responsible for fixing issues in a timely manner.

b. Recommended Improvements

Although the water management plan is followed and manager's discretion is used when appropriate. After review of the water level data from 2011 to 2015 it is apparent that a more active management in structure operations or a change in the water management plan for water levels could alleviate some of the flooding problems. The ability to fully operate the structures during the growing season is critical in maintaining a salinity and water level balance for vegetation to regenerate. The growing season is heavily influenced by south winds, higher tides and elevated water levels that limit the times water can flow out of the system causing above target water levels to occur more often within the project area.

Extreme tides make it difficult to evacuate high water levels. With the current operations, every gate with flaps remain open 100% of the time and Sabine Refuge will open the two small gates at West Cove for brief periods, when possible, during outgoing tides when there is an excess water issue. Under normal operations, all of the gates at Hog Island Gully remain open. It is a balancing act to manage salinity and excess water and our actions depends on salinity and water levels in the Calcasieu Ship Channel. The refuge considers the effects of their structure operations on the neighboring landowners.

c. Lessons Learned

Installation instructions should be written for the installation of the pedestal, stem, and actuator, which state the tolerances to be used.

Dual stems should be considered on slide gates for projects such as this to prevent binding between the gate and guide slots and wear and tear on the actuator and gate mechanisms.

VI. Literature Cited

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APPENDIX A
(Inspection Photographs)

Photo No.1, Hog Island Gully Structure looking from the Hwy 27 side.

Photo No. 2, Hog Island Gully Structure from the Calcasieu Lake side– gates being exercised and in open position

Photo No. 3, Headquarters Structure with outside flapgates flapping

Photo No. 4, Headquarters Structure marsh side culverts with riprap

Photo No. 5, West Cove Canal Calcasieu Lake side of structure with flapgate flapping

Photo No. 6, West Cove Canal from Hwy 27 side – gates being exercised and in open position

APPENDIX B
(Three Year Budget Projection)

SNWR STRUCTURES/ CS-23 / PPL 3

Three-Year Operations & Maintenance Budgets 07/01/2016 - 06/30/2019

Project Manager	O & M Manager	Federal Sponsor	Prepared By
Darrell Pontiff	*Dion Broussard*	*USFWS*	*Dion Broussard*

	2016/2017 (-17)	2017/2018 (-18)	2018/2019 (-19)
Maintenance Inspection	$ 7,057.00	$ 7,269.00	$ 7,487.00
Structure Operation	$ 5,000.00	$ 5,000.00	$ 5,000.00
State Administration			$ -
Federal Administration			$ -
Maintenance/Rehabilitation			

16/17 Description:

E&D	$ -
Construction	
Construction Oversight	
Sub Total - Maint. And Rehab.	$ -

17/18 Description:

E&D	
Construction	
Construction Oversight	
Sub Total - Maint. And Rehab.	$ -

18/19 Description:

E&D	$ -
Construction	$ -
Construction Oversight	$ -
Sub Total - Maint. And Rehab.	$ -

	2016/2017 (-17)	2017/2018 (-18)	2018/2019 (-19)
Total O&M Budgets	**$ 12,057.00**	**$ 12,269.00**	**$ 12,487.00**

O &M Budget (3 yr Total)	**$ 36,813.00**
Unexpended O & M Budget	**$ 527,306.00**
Remaining O & M Budget (Projected)	**$ 490,493.00**

OPERATION AND MAINTENANCE BUDGET WORKSHEET

SABINE REFUGE STRUCTURES / PROJECT NO. CS-23 / PPL NO. 3 / 2016/2017 (-17)

DESCRIPTION	UNIT	EST. QTY.	UNIT PRICE	ESTIMATED TOTAL
O&M Inspection and Report	EACH	1	$7,057.00	**$7,057.00**
General Structure Maintenance	LUMP	0	$0.00	**$0.00**
Engineering and Design	LUMP	0	$0.00	**$0.00**
Operations Contract	LUMP	1	$5,000.00	**$5,000.00**
Construction Oversight	LUMP	0	$0.00	**$0.00**

ADMINISTRATION

LDNR / CRD Admin.	LUMP	0	$0.00	$0.00
FEDERAL SPONSOR Admin.	LUMP	0	$0.00	$0.00
SURVEY Admin.	LUMP	0	$0.00	$0.00
OTHER				$0.00
			TOTAL ADMINISTRATION COSTS:	**$0.00**

MAINTENANCE / CONSTRUCTION

SURVEY

SURVEY DESCRIPTION:					
Secondary Monument	EACH	0	$0.00	$0.00
Staff Gauge / Recorders	EACH	0	$0.00	$0.00
Marsh Elevation / Topography	LUMP	0	$0.00	$0.00
TBM Installation	EACH	0	$0.00	$0.00
OTHER				$0.00
			TOTAL SURVEY COSTS:	**$0.00**

GEOTECHNICAL

GEOTECH DESCRIPTION:					
Borings	EACH	0	$0.00	$0.00
OTHER				$0.00
			TOTAL GEOTECHNICAL COSTS:	**$0.00**

CONSTRUCTION

CONSTRUCTION DESCRIPTION:					
Rip Rap	LIN FT	TON / FT	TONS	UNIT PRICE	
	0	0.0	0	$0.00	$0.00
	0	0.0	0	$0.00	$0.00
	0	0.0	0	$0.00	$0.00
Filter Cloth / Geogrid Fabric		SQ YD	0	$12.00	$0.00
Navigation Aid		EACH	0	$0.00	$0.00
Signage		EACH	0	$0.00	$0.00
General Excavation / Fill		CU YD	0	$0.00	$0.00
Dredging		CU YD	0	$0.00	$0.00
Sheet Piles (Lin Ft or Sq Yds)			0	$0.00	$0.00
Timber Piles (each or lump sum)			0	$0.00	$0.00
Timber Members (each or lump sum)			0	$0.00	$0.00
Hardware		LUMP	0	$0.00	$0.00
Materials		LUMP	0	$0.00	$0.00
Mob / Demob		LUMP	0	$0.00	$0.00
Contingency		LUMP	0	$0.00	$0.00
General Structure Maintenance		LUMP	0	$0.00	$0.00
OTHER				$0.00	$0.00
OTHER				$0.00	$0.00
OTHER				$0.00	$0.00
				TOTAL CONSTRUCTION COSTS:	**$0.00**

TOTAL OPERATIONS AND MAINTENANCE BUDGET: **$12,057.00**

OPERATION AND MAINTENANCE BUDGET WORKSHEET

SABINE REFUGE STRUCTURES / PROJECT NO. CS-23 / PPL NO. 3 / 2017/2018 (-18)

DESCRIPTION	UNIT	EST. QTY.	UNIT PRICE	ESTIMATED TOTAL
O&M Inspection and Report	EACH	1	$7,269.00	**$7,269.00**
General Structure Maintenance	LUMP	0	$0.00	**$0.00**
Engineering and Design	LUMP	0	$0.00	**$0.00**
Operations Contract	LUMP	1	$5,000.00	**$5,000.00**
Construction Oversight	LUMP	0	$0.00	**$0.00**

ADMINISTRATION

LDNR / CRD Admin.	LUMP	0	$0.00	$0.00
FEDERAL SPONSOR Admin.	LUMP	0	$0.00	$0.00
SURVEY Admin.	LUMP	0	$0.00	$0.00
OTHER				$0.00
			TOTAL ADMINISTRATION COSTS:	**$0.00**

MAINTENANCE / CONSTRUCTION

SURVEY

SURVEY DESCRIPTION:					
Secondary Monument	EACH	0	$0.00	$0.00
Staff Gauge / Recorders	EACH	0	$0.00	$0.00
Marsh Elevation / Topography	LUMP	0	$0.00	$0.00
TBM Installation	EACH	0	$0.00	$0.00
OTHER				$0.00
			TOTAL SURVEY COSTS:	**$0.00**

GEOTECHNICAL

GEOTECH DESCRIPTION:					
Borings	EACH	0	$0.00	$0.00
OTHER				$0.00
			TOTAL GEOTECHNICAL COSTS:	**$0.00**

CONSTRUCTION

CONSTRUCTION DESCRIPTION:					
Rip Rap	LIN FT	TON / FT	TONS	UNIT PRICE	
	0	0.0		$0.00	$0.00
	0	0.0	0	$0.00	$0.00
	0	0.0	0	$0.00	$0.00
Filter Cloth / Geogrid Fabric		SQ YD	0	$12.00	$0.00
Navigation Aid		EACH	0	$0.00	$0.00
Signage		EACH	0	$0.00	$0.00
General Excavation / Fill		CU YD	0	$0.00	$0.00
Dredging		CU YD	0	$0.00	$0.00
Sheet Piles (Lin Ft or Sq Yds)			0	$0.00	$0.00
Timber Piles (each or lump sum)			0	$0.00	$0.00
Timber Members (each or lump sum)			0	$0.00	$0.00
Hardware		LUMP	0	$0.00	$0.00
Materials		LUMP	0	$0.00	$0.00
Mob / Demob		LUMP	0	$0.00	$0.00
Contingency		LUMP	0	$0.00	$0.00
General Structure Maintenance		LUMP	0	$0.00	$0.00
OTHER				$0.00	$0.00
OTHER				$0.00	$0.00
OTHER				$0.00	$0.00
				TOTAL CONSTRUCTION COSTS:	**$0.00**

TOTAL OPERATIONS AND MAINTENANCE BUDGET: **$12,269.00**

OPERATION AND MAINTENANCE BUDGET WORKSHEET

SABINE REFUGE STRUCTURES / PROJECT NO. CS-23 / PPL NO. 3 / 2018/2019 (-19)

DESCRIPTION	UNIT	EST. QTY.	UNIT PRICE	ESTIMATED TOTAL
O&M Inspection and Report	EACH	1	$7,487.00	**$7,487.00**
General Structure Maintenance	LUMP	0	$0.00	**$0.00**
Engineering and Design	LUMP	0	$0.00	**$0.00**
Operations Contract	LUMP	1	$5,000.00	**$5,000.00**
Construction Oversight	LUMP	0	$0.00	**$0.00**

ADMINISTRATION

LDNR / CRD Admin.	LUMP	0	$0.00	$0.00
FEDERAL SPONSOR Admin.	LUMP	0	$0.00	$0.00
SURVEY Admin.	LUMP	0	$0.00	$0.00
OTHER				$0.00
			TOTAL ADMINISTRATION COSTS:	**$0.00**

MAINTENANCE / CONSTRUCTION

SURVEY

SURVEY DESCRIPTION:					
Secondary Monument	EACH	0	$0.00	$0.00
Staff Gauge / Recorders	EACH	0	$0.00	$0.00
Marsh Elevation / Topography	LUMP	0	$0.00	$0.00
TBM Installation	EACH	0	$0.00	$0.00
OTHER				$0.00
			TOTAL SURVEY COSTS:	**$0.00**

GEOTECHNICAL

GEOTECH DESCRIPTION:					
Borings	EACH	0	$0.00	$0.00
OTHER				$0.00
			TOTAL GEOTECHNICAL COSTS:	**$0.00**

CONSTRUCTION

CONSTRUCTION DESCRIPTION:					
Rip Rap	LIN FT	TON / FT	TONS	UNIT PRICE	
	0	0.0	0	$0.00	$0.00
	0	0.0	0	$0.00	$0.00
	0	0.0	0	$0.00	$0.00
Filter Cloth / Geogrid Fabric		SQ YD	0	$12.00	$0.00
Navigation Aid		EACH	0	$0.00	$0.00
Signage		EACH	0	$0.00	$0.00
General Excavation / Fill		CU YD	0	$0.00	$0.00
Dredging		CU YD	0	$0.00	$0.00
Sheet Piles (Lin Ft or Sq Yds)			0	$0.00	$0.00
Timber Piles (each or lump sum)			0	$0.00	$0.00
Timber Members (each or lump sum)			0	$0.00	$0.00
Hardware		LUMP	0	$0.00	$0.00
Materials		LUMP	0	$0.00	$0.00
Mob / Demob		LUMP	0	$0.00	$0.00
Contingency		LUMP	0	$0.00	$0.00
General Structure Maintenance		LUMP	0	$0.00	$0.00
OTHER				$0.00	$0.00
OTHER				$0.00	$0.00
OTHER				$0.00	$0.00
				TOTAL CONSTRUCTION COSTS:	**$0.00**

TOTAL OPERATIONS AND MAINTENANCE BUDGET: **$12,487.00**

APPENDIX C
(Field Inspection Notes)

MAINTENANCE INSPECTION REPORT CHECK SHEET

Project No. / Name:CS-23 Sabine Refuge Structure Replacement

Date of Inspection: November 12, 2015 Time: 11:00 a.m.

Structure No. Hog Island Gully Canal

Inspector(s): Dion Broussard (CPRA)
Daryl Clark (USFWS)
Brandon Samson (NRCS) for other inspections

Structure Description: Control Structure

Water Level Inside:N/A Outside: N/A

Type of Inspection: Annual

Weather Conditions: Cloudy skies and cold temperatures

Item	Condition	Physical Damage	Corrosion	Photo #	Observations and Remarks
Steel Bulkhead / Caps	N/A				
Steel Grating	Good				
Gates	Good			1 & 2	
Electrical	Good				
Hardware					
Fencing	Good			1	
Timber Piles	Good				
Timber Wales	N/A				
Actuators	Good			1	Gate 2A needs acuator motor replacement.
Cables	Good				
Signage /Supports	Good				
Rip Rap	Good				
Earthen Embankment	N/A				

What are the conditions of the existing levees?
Are there any noticeable breaches?
Settlement of rock plugs and rock weirs?
Position of stoplogs at the time of the inspection?
Are there any signs of vandalism?

MAINTENANCE INSPECTION REPORT CHECK SHEET

Project No. / Name:CS-23 Sabine Refuge Structure Replacement

Date of Inspection: November 12, 2015 Time: 11:30 a.m.

Structure No. Headquarters' Canal

Inspector(s): Dion Broussard (CPRA)
Daryl Clark (USFWS)
Brandon Samson (NRCS) for other inspections

Structure Description: Control Structure

Water Level Inside:N/A Outside: N/A

Type of Inspection: Annual

Weather Conditions: Cloudy skies and cold temperatures

Item	Condition	Physical Damage	Corrosion	Photo #	Observations and Remarks
Steel Bulkhead / Caps	N/A				
Steel Grating	Good				
Gates	Good			3 & 4	
Electrical	Good				
Hardware	Good				
Timber Piles	Good			3	
Caps					
Timber Wales	Good				
Actuators	Good				
Cables	N/A				
Signage /Supports	N/A				
Rip Rap	Good			3 & 4	
Earthen Embankment	N/A				

What are the conditions of the existing levees?
Are there any noticeable breaches?
Settlement of rock plugs and rock weirs?
Position of stoplogs at the time of the inspection?
Are there any signs of vandalism?

MAINTENANCE INSPECTION REPORT CHECK SHEET

Project No. / Name:CS-23 Sabine Refuge Structure Replacement

Inspector(s): Dion Broussard (CPRA)
Daryl Clark (USFWS)
Brandon Samson (NRCS) for other inspections

Structure No.: West Cove Canal

Water Level Inside:N/A Outside: N/A

Structure Description: Control Structure

Weather Conditions: Cloudy skies and cold temperatures

Type of Inspection: Annual

Item	Condition	Physical Damage	Corrosion	Photo #	Observations and Remarks
Steel Bulkhead / Caps	N/A				
Steel Grating	Good				
Gates	Good			5 & 6	
Electrical	Good				
Hardware/Stairs	Good			5	
Fencing	Good				
Timber Piles	Good				
Timber Wales	N/A				
Actuators	Good			5	
Cables	Good				
Signage /Supports	Good				
Rip Rap	Good			5 & 6	
Earthen Embankment	N/A				

What are the conditions of the existing levees?
Are there any noticeable breaches?
Settlement of rock plugs and rock weirs?
Position of stoplogs at the time of the inspection?
Are there any signs of vandalism?

Appendix D
(Excerpts from Operational Plan)

Excerpts from the "Replace Sabine Structures Operation Plan" from Environmental Assessment 1999

V. DESCRIPTION OF WATER MANAGEMENT PLAN

Operation Goals of the New Water Control Structures. The proposed replacement structures were designed to increase management capabilities and provide greater water discharge capability than the existing structures (Table 1). The operational plan for the new structures has been developed to maintain the existing marsh types and provide the following goals:

1) To increase water discharge capacity and reduce adverse impacts from excessive rainfall and storm surges which push excessive saline water into the area,

2) To curtail saltwater intrusion into interior low-salinity marshes, and

3) To provide greater cross-sectional area for improved estuarine-dependent fish and shellfish access.

The water management plan for each new structure provides for unimpeded water exchange through a cross-sectional area approximately equivalent to that of the existing structure when fully open. Additional water exchange would be allowed, upon the refuge manager's discretion, for the purpose of discharging excess water, introducing fresh water or water of lower salinity, improving ingress and egress of estuarine-dependent fishes and shellfishes, and discharging anoxic water or to remediate other water quality problems.

The operational plan would also allow the new structures to restrict or halt saltwater inflow to protect intermediate marshes from saltwater damage. The intermediate marsh areas occur primarily within the northwestern and southwestern portions of the project area. Intermediate marshes also occur beyond the western project area boundary along Central Canal. Saltwater intrusion into these areas occurs primarily through Central Canal and through the open water area of the northeastern project area adjacent to Sabine NWR Management Unit 1. Two data collection platforms (Stations' BC and BN) have been established along each of these two saltwater routes to monitor the rate and extent of saltwater penetration into project area intermediate marshes (Figure 2).

Because Station BC is located at a site from which saltwater readily enters intermediate marshes to the south, west, and north, it was determined to be a critical salinity monitoring station. Station BN is in an intermediate marsh area, hence it was also determined to be a critical monitoring station.

Station BN and Station 5R Structure Operation Criteria. Salinity data compiled for stations BN and BC reveal that the period 1984 through 1988 was the most saline on record, and the period 1989 through 1993 was the freshest on record. Mean monthly salinities were plotted for both the 1984-1988 and 1989-1993 periods (Figures 3 and 4). To maintain existing intermediate marsh vegetation, it was assumed that maintenance of an appropriate salinity range would be most critical during the beginning and middle portions of the growing season from March through August. The new structures will be operated to maintain growing season salinities at Station BN between that of the 1984-88 and 1989-93 extremes. Hence, 3 parts per thousand (ppt) was established as the Station BN structure closure criteria (Water Control Structure Operational Plan-Attachment 1). Given that high salinity events occur with greater frequency from September through February, the Station BN closure criterion during this period was established at 5 ppt (the lower range of the monthly maximum values).

Saltwater may reach Station BN by either flowing northward up Beach Canal from the West Cove Canal Structure, or it may flow across open water areas in Unit 1 from the Hog Island Gully Structure. Station 5R was established to monitor the influence of saltwater inflows through the Hog Island Gully Structure on Unit 1 open water areas. Salinity criteria were established for Station 5R to restrict saltwater inflows and reduce the potential that east or southeast winds will push high salinity waters across Unit 1 and exceed closure criteria at Station BN. To establish those inflow restriction criteria at Station 5R, four years of simultaneous readings from Stations BN and 5R were compared. Those data revealed that Station 5R salinities averaged 2.4 ppt higher than those at Station BN. For this reason, inflow restriction salinity criteria at Station 5R were established 2 ppt higher than closure criteria at Station BN.

Saltwater inflow restrictions to protect intermediate marshes in the vicinity of Station BN would also be triggered when salinities at Station BN reached levels 1 ppt less than the closure criteria. When salinities at Station BN reach the inflow restriction criteria, refuge personnel will utilize other salinity data, precipitation, wind direction,

wind speed, east Unit 3 spillway operations and other factors to determine whether the saltwater came from the Hog Island Gully Structure or from the West Cove Canal Structure. Only those refuge structure(s) determined to have caused the high salinity conditions will be closed or restricted. Should refuge personnel determine that the saltwater came from both the West Cove and Hog Island Gully Structures, then both structures will be closed. Additional safeguards against saltwater intrusion from the south via Beach Canal will be provided by the criteria at monitoring Stations C and BC.

Station BC and Station C Structure Operation Criteria. Station BC is located in a deteriorated brackish marsh area (Figure 5). This station will monitor salinity inflows primarily from the West Cove Canal and Headquarters's Canal structures prior to the dispersal of those flows to the south, west, or north. Because of the salinity fluctuations at Station BC, mean salinities during 1984-88 and 1989-93 (Figure 4) were used less than the unaveraged data presented in Tables 2 and 3. Based upon that data, gate closure criteria were chosen between the extremely high salinity conditions of 1984-88 and the low salinity conditions of 1989-93. The March-August salinity criteria for gate closure was determined to be 6 ppt, and the September-March salinity closure criteria was determined to be 10 ppt (Water Control Structure Operational Plan-Attachment 1).

To protect intermediate marshes located to the north, west, and south, of Station BC, and to reduce the extent of complete gate closures triggered by those high salinities, Station C was established to monitor saltwater inflows heading for Station BC. Salinity values at Station C, which trigger inflow restrictions through the West Cove Canal and Headquarters Canal Structures, were determined by readings from July 1990 through August 1998. During this period, Station C salinities averaged 2.1 ppt higher than those at Station BC. Therefore, the growing season inflow restriction criteria at Station C were set 2 ppt higher than the Station BC structure closure criteria. Given that saltwater inflows here are contained within canals, the non-growing season inflow restriction criteria at Station C was set at the same value as Station BC closure criteria to ensure that intermediate marshes are not impacted. Hence Station C inflow restriction criteria are 8 ppt during the growing season and 10 ppt during the non-growing season (Water Control Structure Operational Plan-Attachment 1). Additionally, should Station BC salinities reach or exceed 4 ppt during the growing season, or 8 ppt during the non-growing season (that is 80 percent of closure criteria values), then the Headquarters' Canal and West Cove Canal Structures may be operated to restrict saltwater inflows.

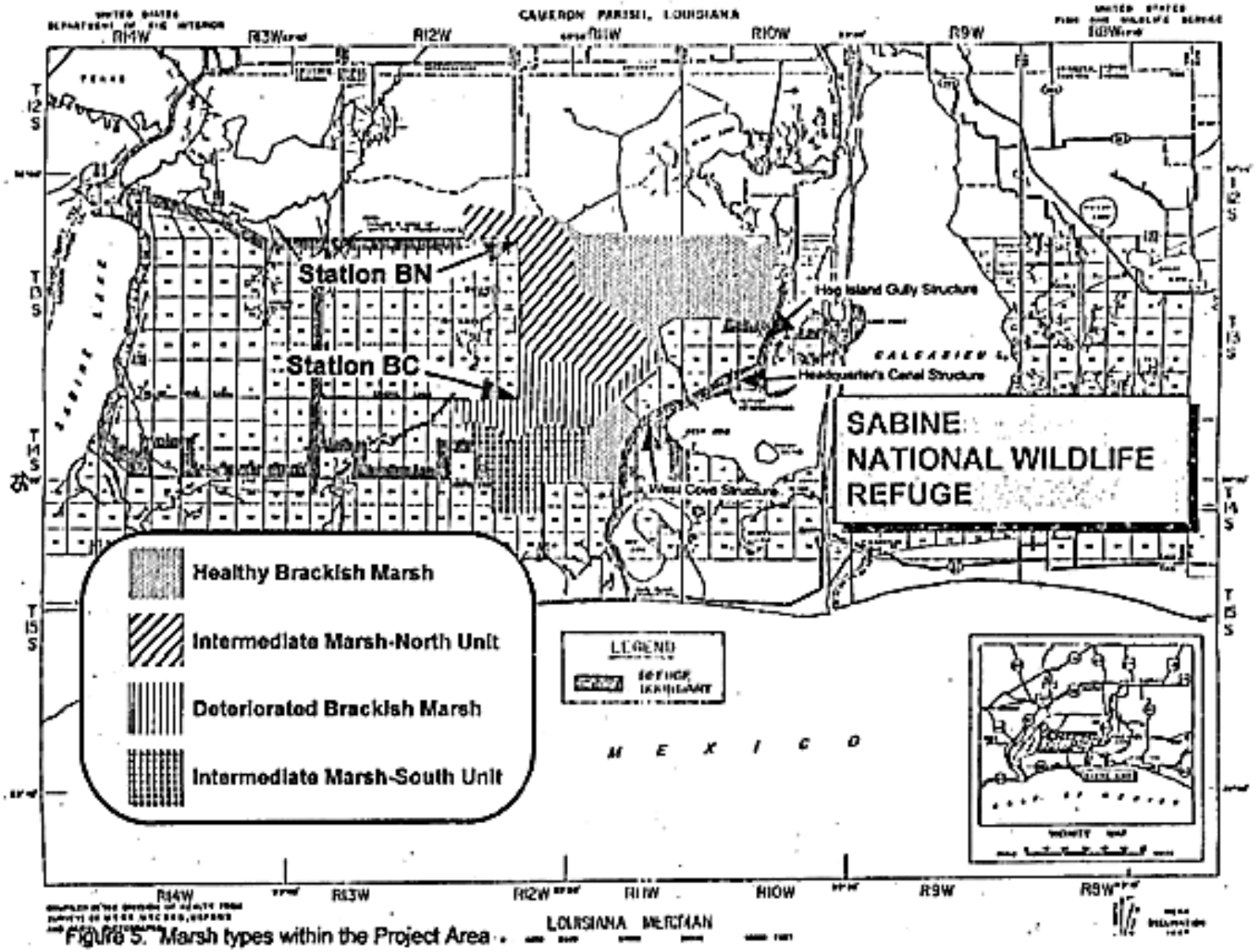

Figure 5. Marsh types within the Project Area.

Station BS Structure Operation Criteria. Salinity monitoring conducted at Station BS (located at the intersection of Beach Canal and Southline Canal) will ensure that saltwater does not adversely impact intermediate marshes south of the project area. Saltwater reaching this station would likely come from the West Cove Canal Structure via Central Canal. However, it might also come via the East Mud Lake area through South Line Canal, or from high tides overtopping the beach rim. Station BS salinity criteria for restricting saltwater inflow and closing structures will be the same as those at Station BC (6‰-growing season; 10‰-non-growing season). When those criteria are met, refuge personnel will evaluate other salinity data, tides, precipitation, wind speed and direction, plus other factors to determine the source of saltwater. If refuge personnel determine that salinities came from Central Canal, then the Headquarters Canal and West Cove Canal structures will be closed or restricted as appropriate. If the saltwater at Station BS is determined to have come over the beach rim, then, pending refuge manager discretion and conditions elsewhere, refuge structures will likely be left open to discharge that water.

Inflow Restriction Criteria Summary and Structure Operations. When the salinities reach or exceed any of the salinity criteria specified below (see Table 4), the refuge manager will determine the source of high salinity water causing the criteria to be reached or exceeded. Only those refuge structure(s) determined to be admitting the saltwater will then be operated to restrict future saltwater inflows. During inflow restriction operations and all periods when water level safety provisions are not in effect, the refuge manager may use his discretion to configure the flapgates and/or other gates to discharge water as desired. When the salinity levels at the station(s) prompting inflow restrictions fall below the inflow restriction criteria, then normal water exchange will be resumed.

Restricted inflow through the Hog Island Gully Structure will be achieved by allowing inflow through only one, fully open, 3-foot-wide gate (22% of normal cross-section). Restricted inflow through the West Cove Canal Structure will be achieved by completely closing the Headquarters' Canal structure to all inflow and by restricting inflow at the West Cove Canal Structure to only one, fully open, 3-foot-wide gate (20% of normal combined cross-section), or, by completely closing the West Cove Canal Structure and allowing exchange through one Headquarters Canal culvert opened 75 percent.

Table 4. Salinity criteria (ppt) for restricting saltwater inflows

		Monitoring Station				
Season	Months	C	BC	BS	5R	BN
Growing	Mar. - Aug.	8	4	4	5	2
Non-growing	Sep. - Feb.	10	8	8	7	4

Gate Closure Criteria Summary and Structure Operations. When the salinities reach or exceed any of the salinity criteria specified below (see Table 5), the refuge manager will determine the source of that saltwater. Only those refuge structure(s) determined to be admitting the saltwater will then be operated to preclude further saltwater inflow. During periods of gate closures and all periods when water level safety provisions are not in affect, the refuge manager may use his discretion to configure the flapgates and/or other gates to discharge water as desired. When the salinity levels at the station(s) prompting gate closures fall below the closure criteria, then normal or restricted inflow operations will be resumed depending on area salinities.

Table 5. Salinity criteria (ppt) for halting all saltwater inflows

		Monitoring Station				
Season	Months	C	BC	BS	5R	BN
Growing	Mar. - Aug.	-	6	6	-	3
Non-growing	Sep. - Feb.	-	10	10	-	5

Special Gate Openings for Marine Organism Ingress and Egress. When salinity criteria (Table 5) provide for complete elimination of inflows, short-term special gate openings will be conducted to provide ingress and egress as follows:

a) ***March 1st through April 15th.*** During this critical brown shrimp ingress period, one 3-foot-wide gate will be completely open, during incoming tides, at night

only, for 3 to 6 hours per day, for 3 consecutive nights each week. Those openings should be targeted for post-dusk or pre-dawn periods, to the degree possible.

b) ***May 15th through June 14th.*** During this critical brown shrimp egress period, a minimum of one 3-foot-wide gate should be fully opened during outgoing tides, for a 6-8 hour period, once a week. Those openings should be conducted during periods of darkness to the greatest degree possible.

c) ***June 15th through July 31st.*** During this critical white shrimp ingress period, one 3-foot-wide gate will be completely open, during incoming tides, at night only, for 3 to 6 hours per day, for 3 consecutive nights each week. Those openings should be targeted for post-dusk or pre-dawn periods, to the degree possible.

d) ***Opening of white shrimp season through Nov. 31st.*** During this white shrimp egress period, special openings should be conducted during outgoing tides, in conjunction with the opening of white shrimp season. Following that, openings should be conducted 3 to 4 times a month, and/or associated with the passage of cold fronts.

e) ***September 1st through September 30th.*** During this ingress period for red drum, one 3-foot-wide gate will be completely open, during incoming tides, at night only, for 3 to 6 hours per day, for 3 consecutive nights each week. Those openings should be targeted for post-dusk or pre-dawn periods, to the degree possible.

Structure Operations During Periods of High Water Levels. Marsh elevation will be determined and staff gauges installed to provide information on project area water levels (Figure 6). Water level data from those staff gauges and from project area DCP's will be used to trigger special gate openings to facilitate discharge of excess water. Generally, if interior marsh water levels exceed the marsh surface [*defined as the surface of the marsh sediment at the base of marsh vegetation at the juncture of the marsh plant shoots and marsh floor (or mud/detritus surface)*] by two inches for two weeks, then sluice gates on each flapgated bay will be raised to discharge excess water. Under such conditions, all inflow through non-flapgated bays will be halted until project area water levels are dropping and at or below two inches above marsh level. At that time, normal exchange will be resumed. During periods of normal water levels, the refuge manager, may allow discharge through flapgated bays according to his discretion.

Structure Operations During Tropical Storms. Prior to a storm's approach, flapgated bays may be readied in advance for later discharge of excess water by raising the interior sluice gates of those bays equipped with flapgates. Prior to a storm's approach, refuge personnel may restrict or close non flapgated bays to reduce exposure of interior marshes to saltwater tidal surges. Following a storm, normal or restricted water exchange operations shall be resumed on non-flapgated bays in accordance with the established salinity and water level provisions and criteria.